U.S. Department of Energy - FreedomCAR & Vehicle Technologies Program
(Advanced Vehicle Testing Activity)

Hydrogen Fuel Pilot Plant and Hydrogen ICE Vehicle Testing

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National Hydrogen Association Conference
March 2005

Presentation Outline

- **Background and Goal**
- **Testing partners**
- **Alternative Fuel Pilot Plant – design & operations**
- **Fuel dispensing**
- **Prototype dispenser testing**
- **Hydrogen internal combustion engine (ICE) vehicle testing activities**
- **Gen II station design**
- **Contact information & obtaining reports**

Advanced Vehicle Testing Activity (AVTA)- Background

- **AVTA is part of the U.S. Department of Energy's FreedomCAR and Vehicle Technologies Program**

- **AVTA Goal - Benchmark & validate the performance of light-, medium-, & heavy-duty vehicles that feature one or more advanced technologies, including:**
  - **ICE's burning advanced fuels, such as 100% hydrogen & hydrogen/CNG-blended (H/CNG) fuels**
  - **Hybrid electric, pure electric, & hydraulic drive systems**

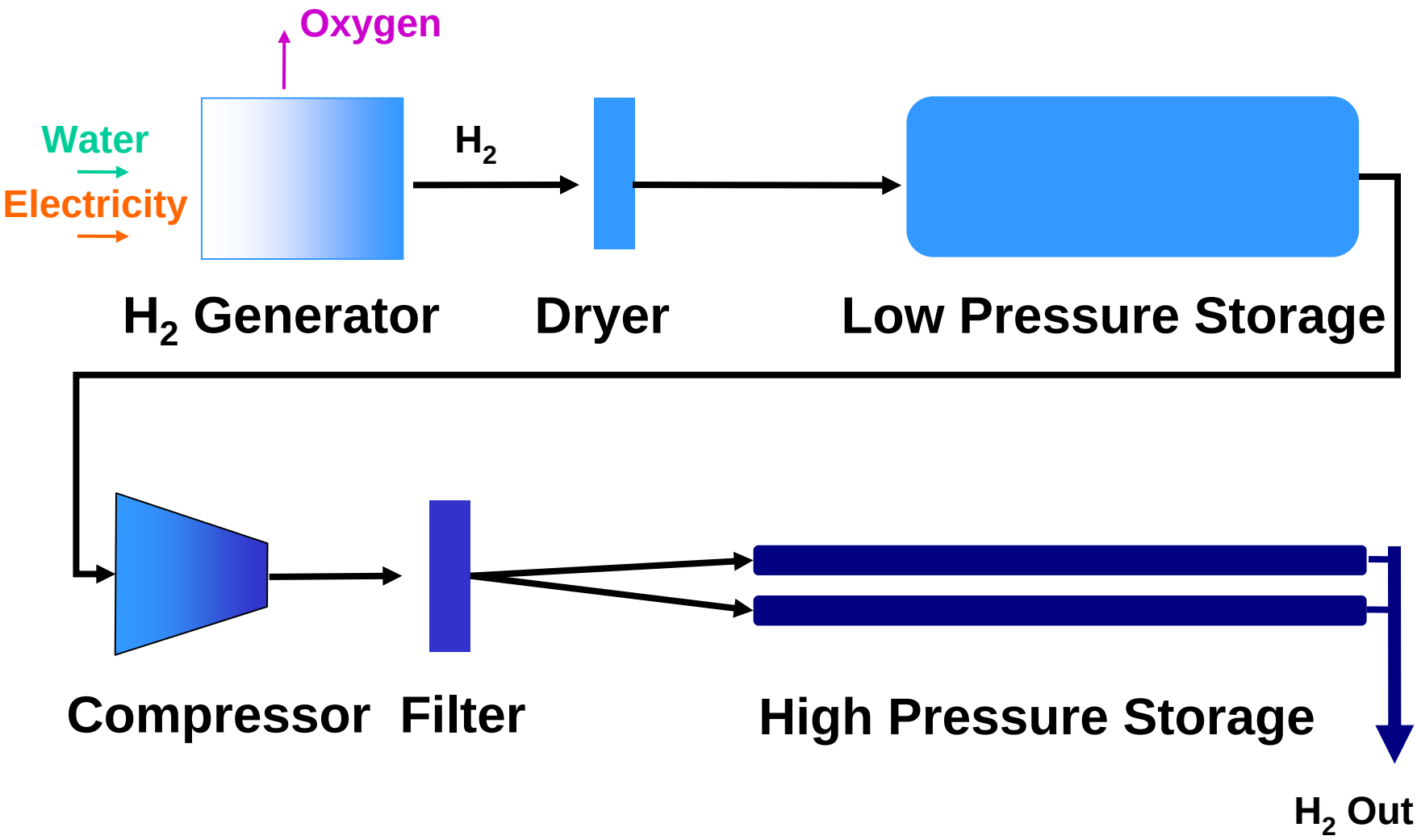
APS Alternative Fuel (Alt-Fuel) Pilot Plant & Vehicle Testing - Partners

- **Arizona Public Service (APS)**
- **Electric Transportation Applications (ETA)**
- **DOE's Advanced Vehicle Testing Activity (AVTA)**
- **Idaho National Laboratory (INL) – manages, analyzes, and disseminations these AVTA testing activities and results**

APS Alt-Fuel Pilot Plant & Vehicle Testing - Objectives

- **Evaluate the safety & reliability of operating ICE vehicles on hydrogen & H/CNG blended fuels**
- **Evaluate hydrogen fueling infrastructure costs**
- **Quantify hydrogen & H/CNG ICE vehicle costs, performance, & emissions**

APS Alt-Fuel Pilot Plant - Hydrogen System

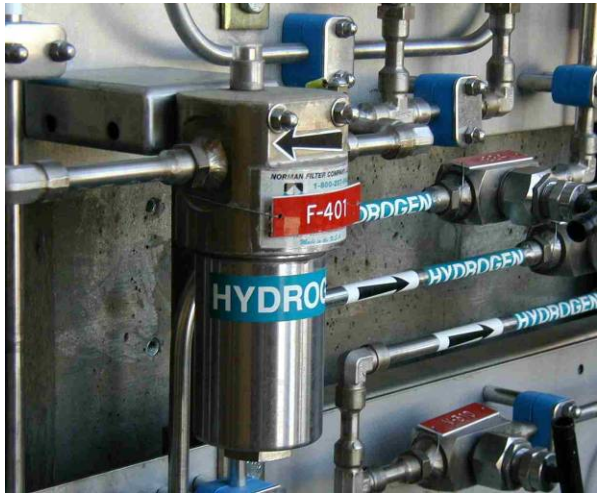


APS Alt-Fuel Pilot Plant – Hydrogen System

- **Proton Energy Systems' HOGEN PEM stationary fuel cell operating in reverse**
  - **300 scfh hydrogen output @ 150 psi**
  - **17 kWh per 100 scf hydrogen**
- **Hydrogen Lectrodryer**
  - **300 scfh**
  - **-80°F dew point**

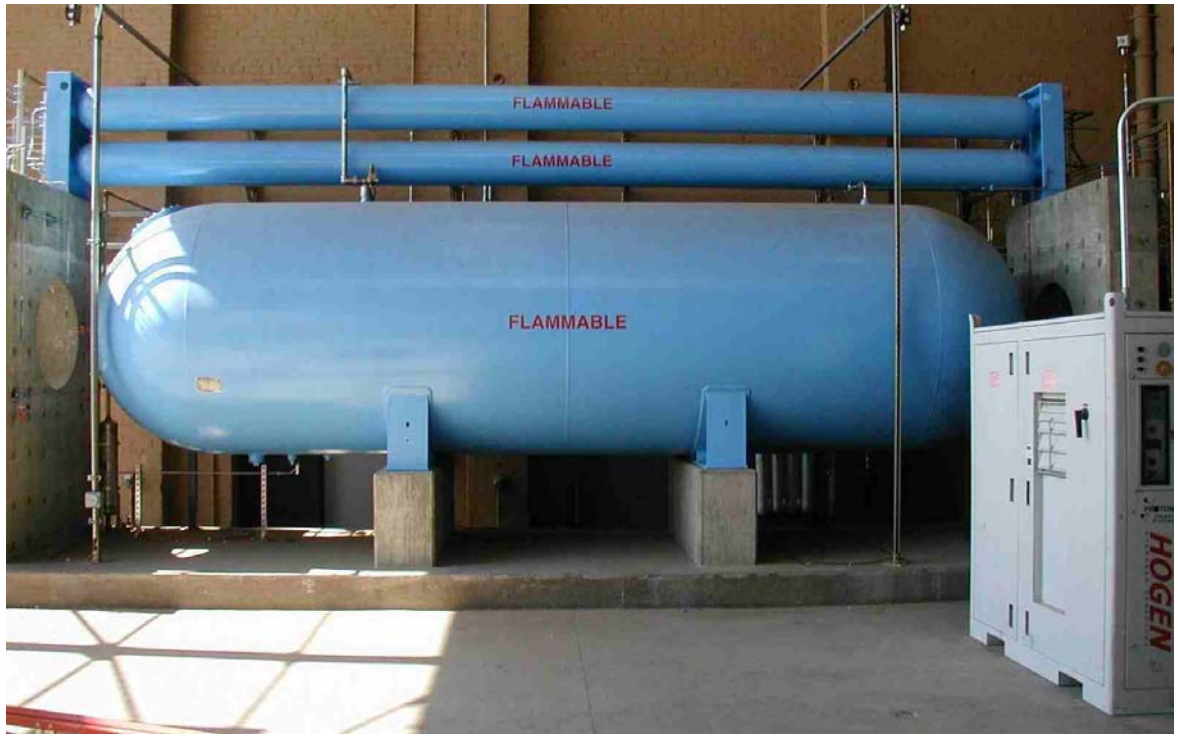
APS Alt-Fuel Pilot Plant – Hydrogen System

- Hydrogen compressor
  - Pressure Dynamic Consultants (Pdc Machines)
  - Oil-free triple diaphragm
  - Two-stage compression
  - 300 scfh @ 6,100 psi
- Norman hydrogen filter locations
  - High- & low-pressure storage outlets
  - Dryer inlet & outlet
  - Compressor outlets
- Hydrogen - 99.9997% purity



APS Alt-Fuel Pilot Plant - Hydrogen System

- **Low pressure hydrogen storage (lower tank)**
- **High pressure hydrogen storage (upper 2 tanks)**



Low Pressure Hydrogen Storage Tank

- **8,955 scf @ 150 psi**
- **Rated for 250 psi @ 125°F**
- **Carbon steel, 6 ft. 11 in. inside diameter, 19 ft. long**
- **Water volume of 6,565 gal.**
- **Manufactured by Trinity Industries under ASME Pressure Vessel Code**
- **ASME safety relief valve rated @ 165 psi piped to vent stack**

High Pressure Hydrogen Storage Tanks

- **17,386 scf @ 6,000 psi (total both tanks)**
- **Rated for 6,667 psi @ 200°F**
- **Seamless horizontal carbon steel, 16 in. outside diameter, 28 ft. long**
- **Water volume of 405 gal. (total both tanks)**
- **Manufactured by CP Industries under 1998 ASME Pressure Vessel Code**
- **ASME safety relief valve rated @ 6,667 psi piped to vent stack**

APS Alt-Fuel Pilot Plant - Auxiliary Systems

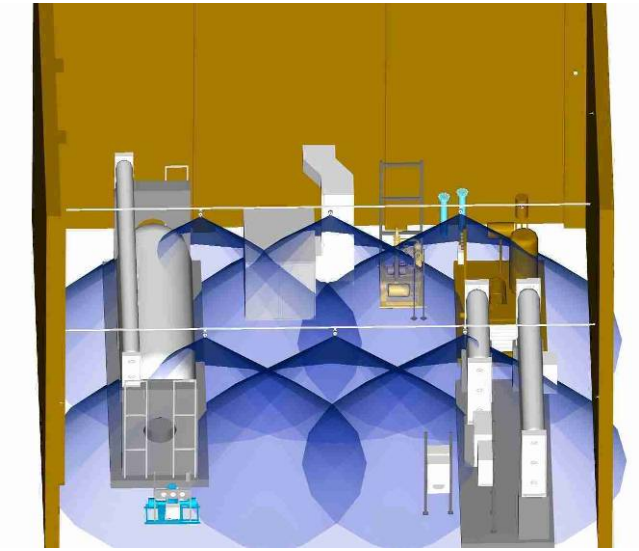
- **Water Purification - 215 gal/day, 1.0 micron exit filter**
- **Control Air - 100 cfm compressor, 90 psi**
- **Chiller - 293,000 Btu/h,**
- **Nitrogen - Air/hydrogen buffer gas - production, piping, compression & 600 scf storage. 97% purity @ 100 psi**
- **Helium - vent stack purging**
- **Vents - fabricated from 0.5 in. 304 stainless steel tubing, 3 in. schedule 40 stainless steel pipe**

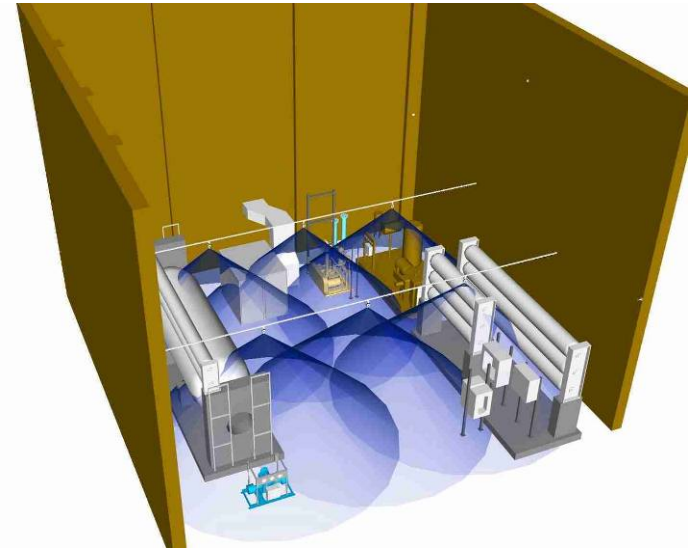
APS Alt-Fuel Pilot Plant - Emergency Shutdown System (EMS)

- **Ultra-fast IR/UV detectors**
- **Combustible gas detectors**
- **Manual (5) & remote trips**
- **Vent stack temperature monitor**
- **Alarms horns and strobe lights**
- **Vent stack fire suppression**

APS Alt-Fuel Pilot Plant - EMS

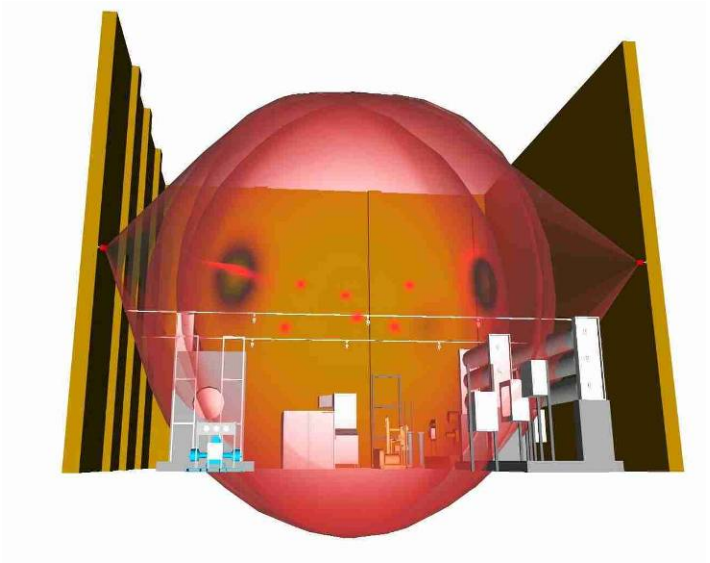
- **Six combustible gas detectors (Det-Tronics RS 8471)**
- **Monitors hydrogen & natural gas in 1% increments of lower flammability limits (LFL)**
- **Alarm condition at 25% of LFL reached**
- **Emergency shutdown when 50% of LFL reached**

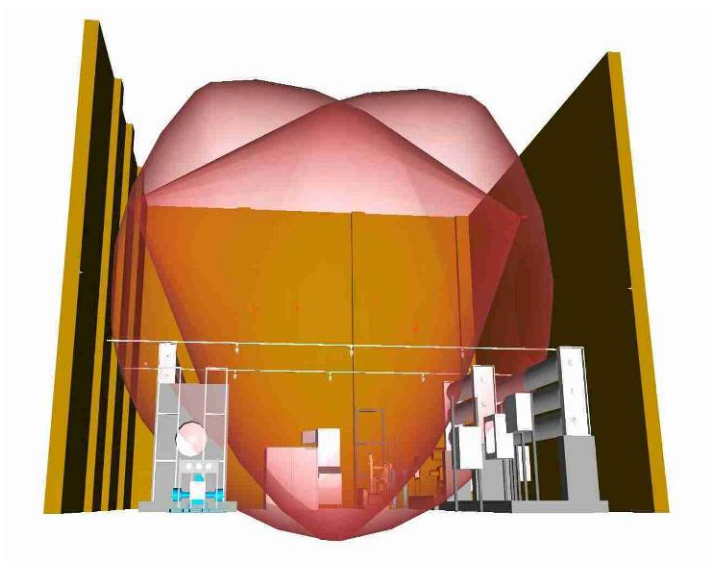




APS Alt-Fuel Pilot Plant - EMS

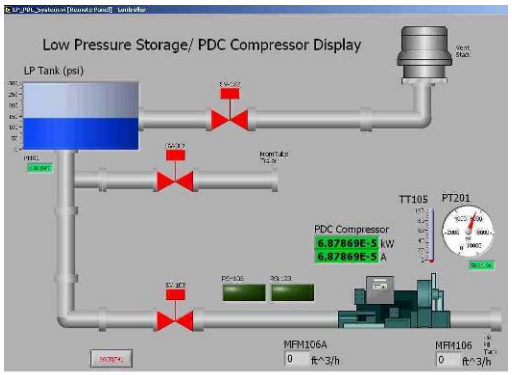
- **Two mid-level (35 feet) & four corner IR/UV flame detectors (Spectrex 20/20LB units)**
- **One detector at fuel dispenser unit**
- **If flame detected, emergency shutdown initiated within 3 milliseconds**

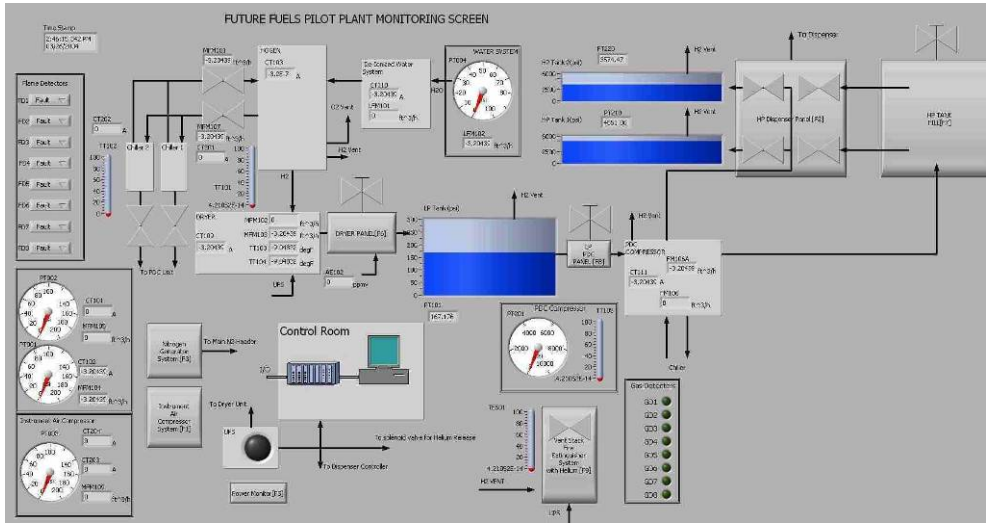




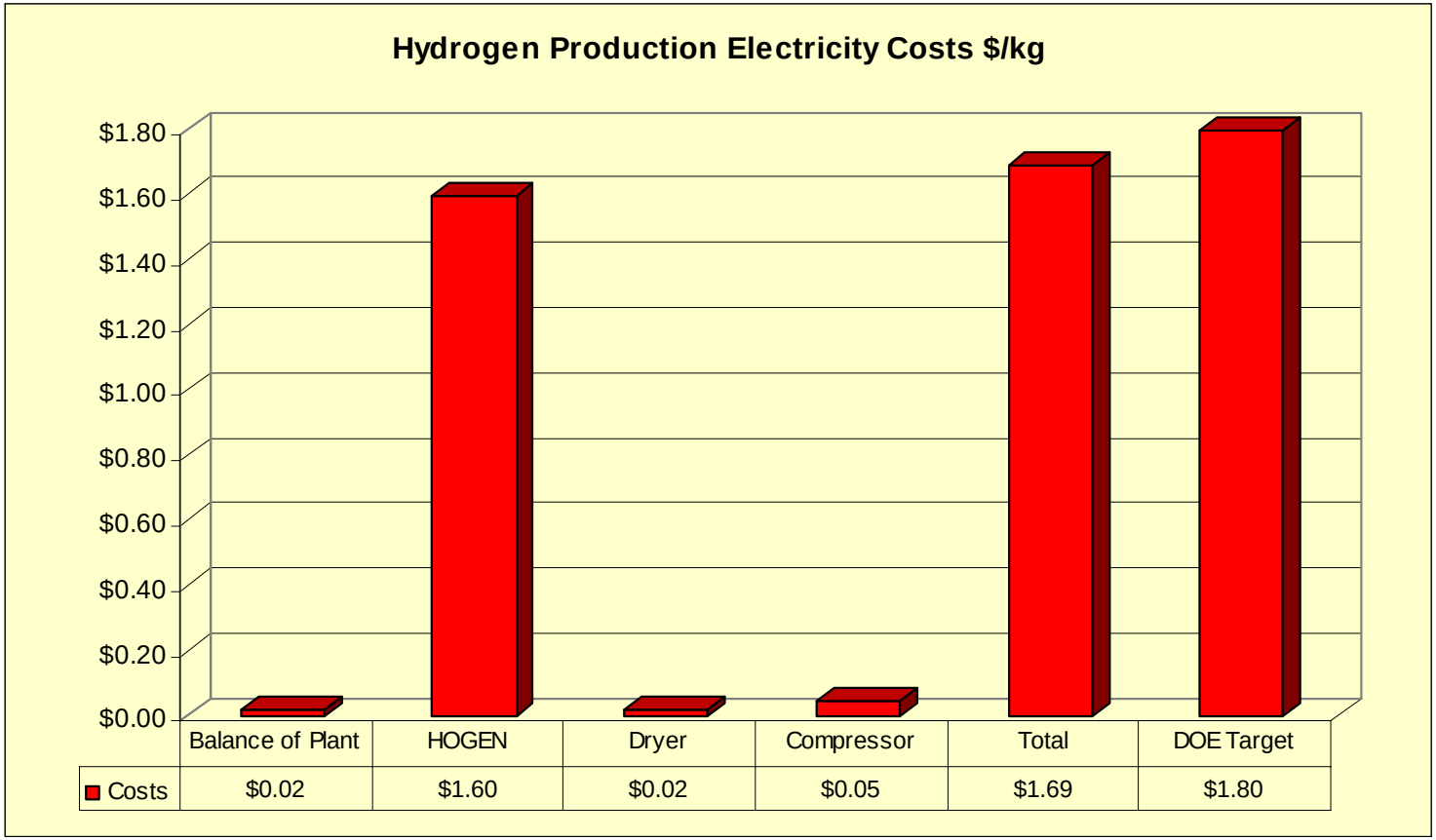
APS Alt-Fuel Pilot Plant - Monitoring System

- **Real-time station & component monitoring @ 50 monitoring nodes (100 @ completion)**
- **Fuel quantities collected and costs calculated for pure hydrogen and H/CNG blended fuels**
- **Electric powered equipment**
  - **Voltages & currents**
- **Select process temperatures**
- **Major process parameters**
  - **Pressures & flows**



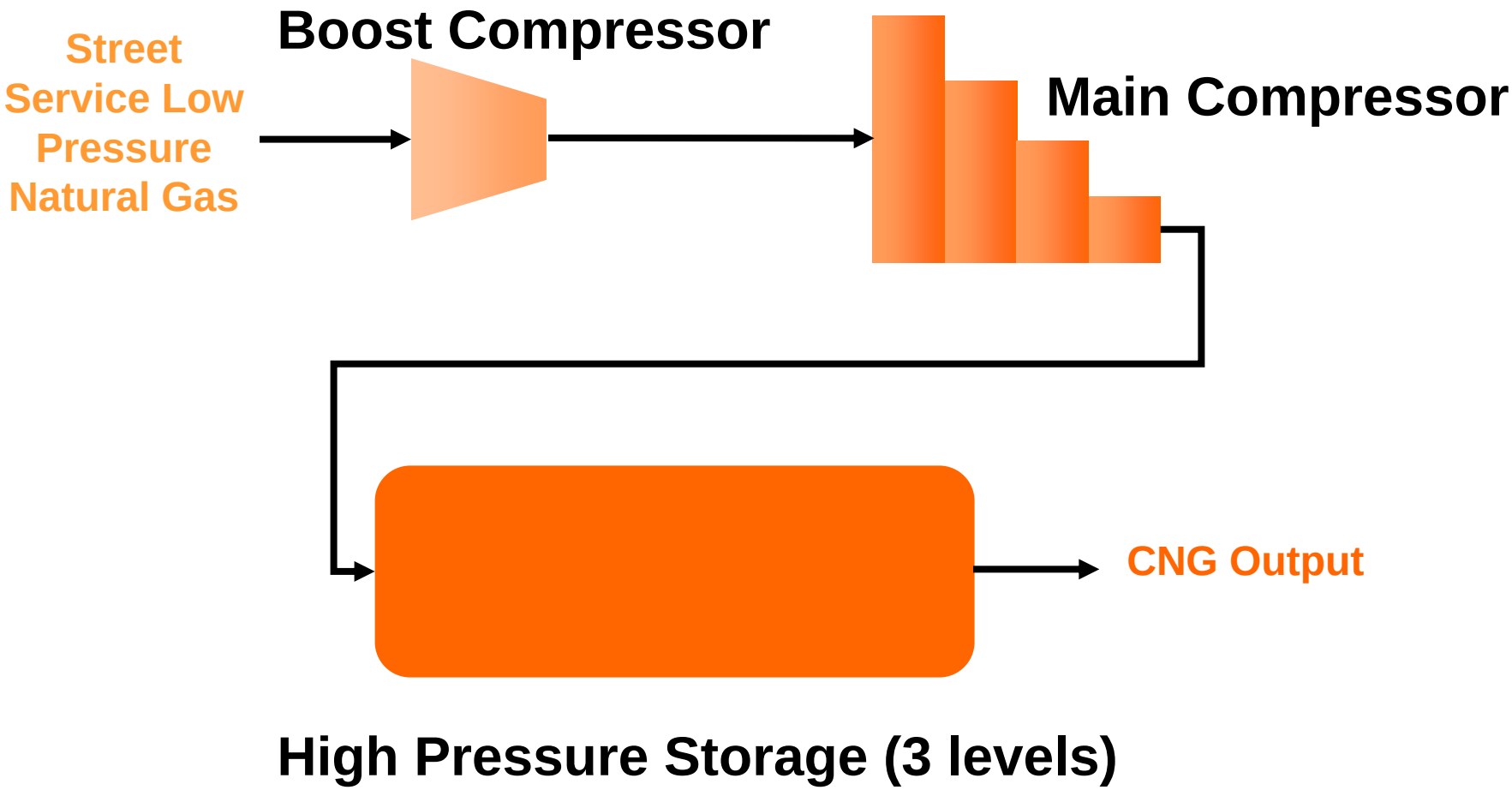


APS Alt-Fuel Pilot Plant – Monitoring System



DOE 2005 Electricity Target ($1.80) for a refueling station producing 250 kg/day. APS Hydrogen Production Electricity Cost based on APS published commercial/industry rate of $0.02/kWh for 5 MW & larger.

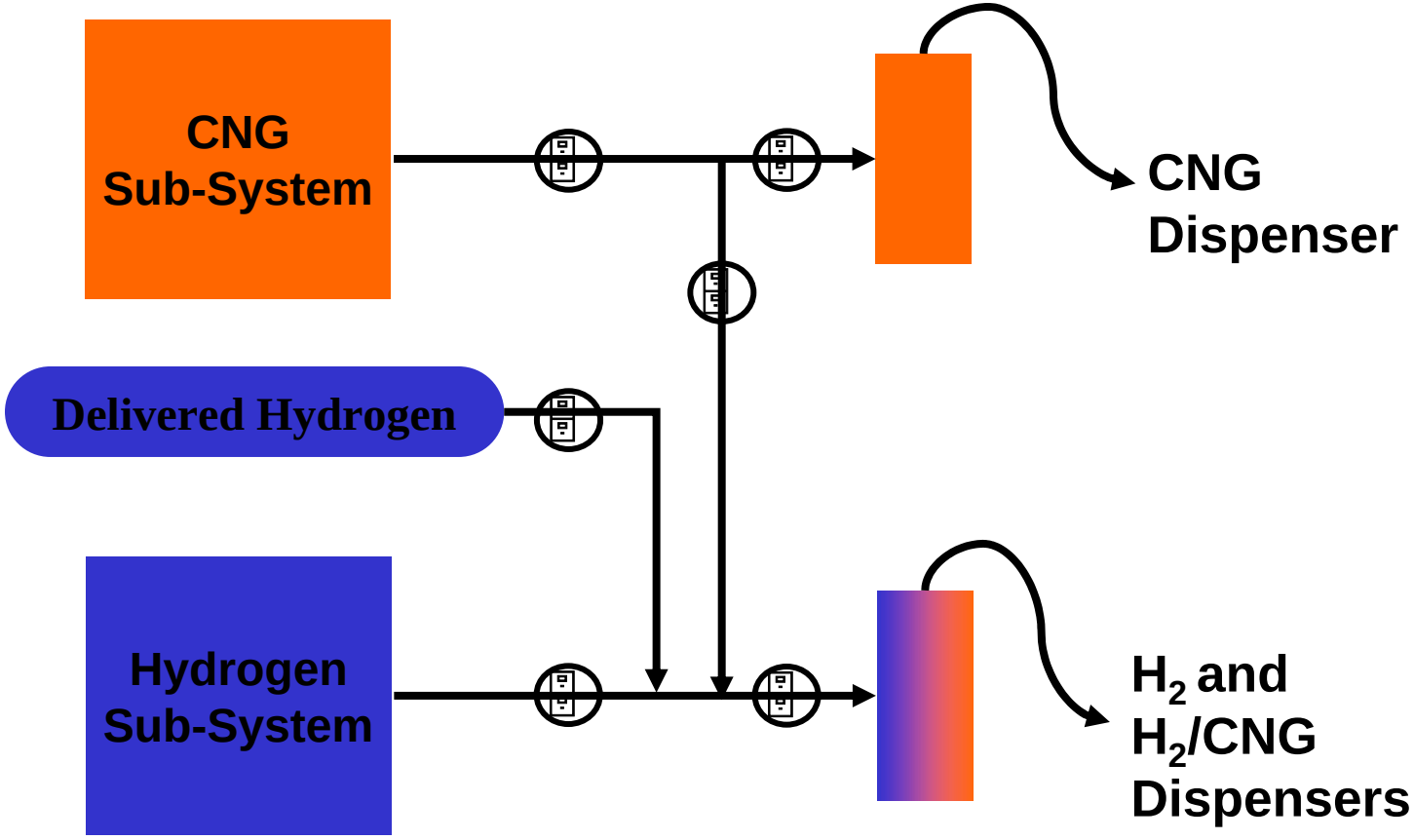
APS Alt-Fuel Pilot Plant - CNG System



APS Alt-Fuel Pilot Plant - CNG System

- **CNG Boost Compressor**
  - **300 scfm @ 60 psi**
- **CNG Main Compressor**
  - **350 scfm @ 5,000 psi**
- **CNG Storage/Pressure – 6 tanks**
  - **3 Low: 11,079 scf @ 3,600 psi**
  - **2 Medium 5,711 scf @ 4,500 psi**
  - **1 High: 5,711 scf @ 5,000 psi**
  - **Manufacturer: CP Industries**

APS Alt-Fuel Pilot Plant – Dispenser System

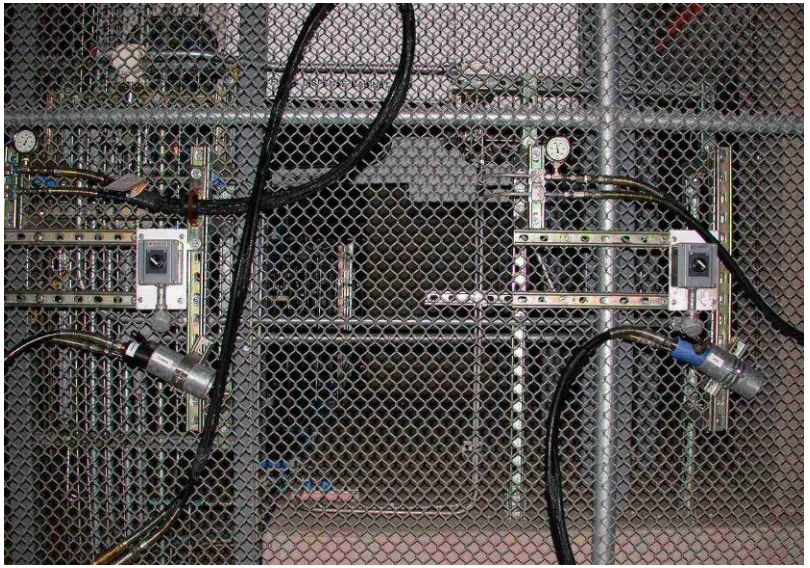


APS Alt-Fuel Pilot Plant - Fueling Dispensers

- **Includes metering & electronic billing Interface**
- **Fully permitted for motor fuel dispensing**
- **Public access**

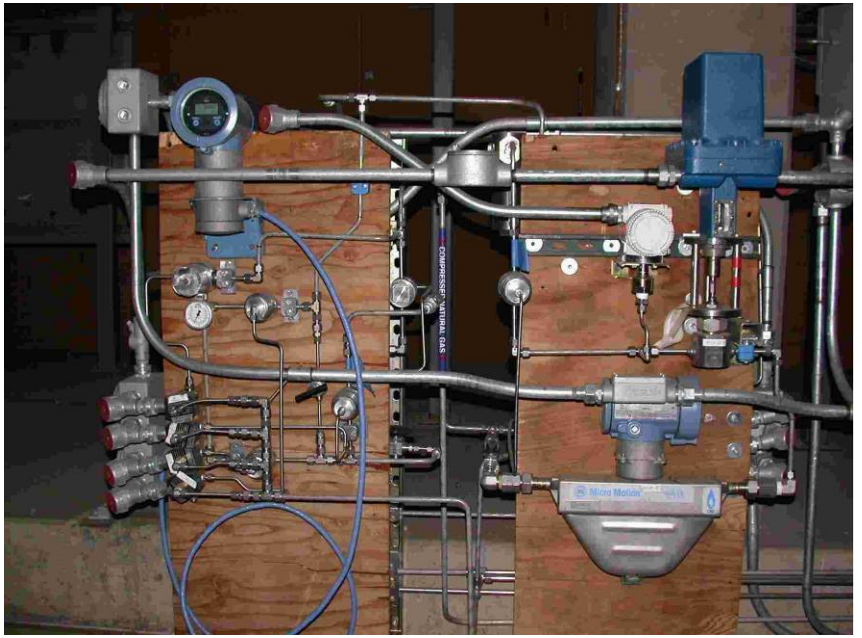
Prototype Dispenser Testing

- **Uses proportional flow control valves for hydrogen & CNG gas streams to control gas flow rates from 100 to 40,000 scfh**
- **Dispenser controller adjusts the control valves to provide real-time ratio control of blended fuels**
- **Control valves are trimmed by a digital dispenser controller using mass flow signals provided by coriolis mass flow transducers in the hydrogen & CNG gas streams**



Prototype Dispenser Testing

- **Delivers 100% hydrogen, 100% CNG, & blends of H/CNG using two independent single nozzles to AVTA test vehicles**
- **1 Nozzle - CNG and H/CNG fuels (15, 20, 30, & 50% hydrogen - by volume) at 3,600 psi**
- **1 Nozzle - 100% hydrogen dispensing at 5,000 psig**
- **Next step – commercial package**



Hydrogen & H/CNG ICE Vehicle Testing

- **Initial ICE hydrogen & H/CNG vehicle testing**
  - **Ford F150 up to 30% H/CNG (continues in testing)**
  - **Ford F150 up to 50% H/CNG (testing complete)**
  - **100% hydrogen Mercedes Benz van (operating)**
  - **Dodge van on 15% H/CNG (continues in testing)**

Hydrogen/CNG ICE Vehicle Testing

- **Ongoing hydrogen & H/CNG ICE vehicle testing**
  - **8 APS fleet vehicles on 15% H/CNG - S-10s, Sierra pickups, Blazers, Dodge Ram van**
  - **16+ City of Phoenix (including Phoenix Fire Department) fleet vehicles on 15% H/CNG**

Hydrogen/CNG ICE Vehicle Testing

- **100% hydrogen ICE vehicle Baseline Performance and Fleet testing**
  - **Ford F150 – 100% hydrogen, 5.4 liter 16 valve**
  - **Ford F150 - 100% hydrogen, 5.4 liter, 32 valve**
  - **Adding another V-8 pickup**
- **250,000+ hydrogen & H/CNG test miles, 3,000+ successful fueling events**

5.4L 16-valve Hydrogen ICE Vehicle Testing

- **Ford 16-valve 5.4L SOHC V-8, 100% hydrogen, fuel injected, supercharged, & 1,365 lbs payload**
- **Converted by Electric Transportation Engineering Corporation (eTec)**
- **Onboard hydrogen storage**
  - **3 Dynetek tanks**
  - **Aluminum inner vessel, fiberglass wrap**
  - **3,000 psi**
  - **6.5 kilograms**

5.4L 16-valve Hydrogen ICE Vehicle Testing

- **Baseline Performance testing results**
  - **Maximum speed @ 1 mile: 81 mph & ¼ mile: 58 mph**
  - **Acceleration (0 to 50 mph): 18.1 seconds**
  - **SAE J1634 fuel economy (AC on): 14.5 miles/GGE**
  - **SAE J1634 fuel economy (AC off): 18.0 miles/GGE**
  - **45 mph constant speed fuel economy: 27.0 miles/GGE**
  - **Range 95 to 175 miles (6.5 GGE storage)**
- **Started Fleet testing**
  - **2,800 miles: 17.2 miles/GGE**

5.4L 32-Valve 100% Hydrogen ICE - Status

- Engine changed to 10.5 to 1 compression, 12 pounds supercharge boost
- To be Baseline Performance and Fleet tested
- Fuel storage
  - 3 Dynetek tanks
  - Aluminum inner vessel, carbon wrap
  - 5,000 psi tanks
  - 15 kilograms

30% H/CNG F150 Performance Testing

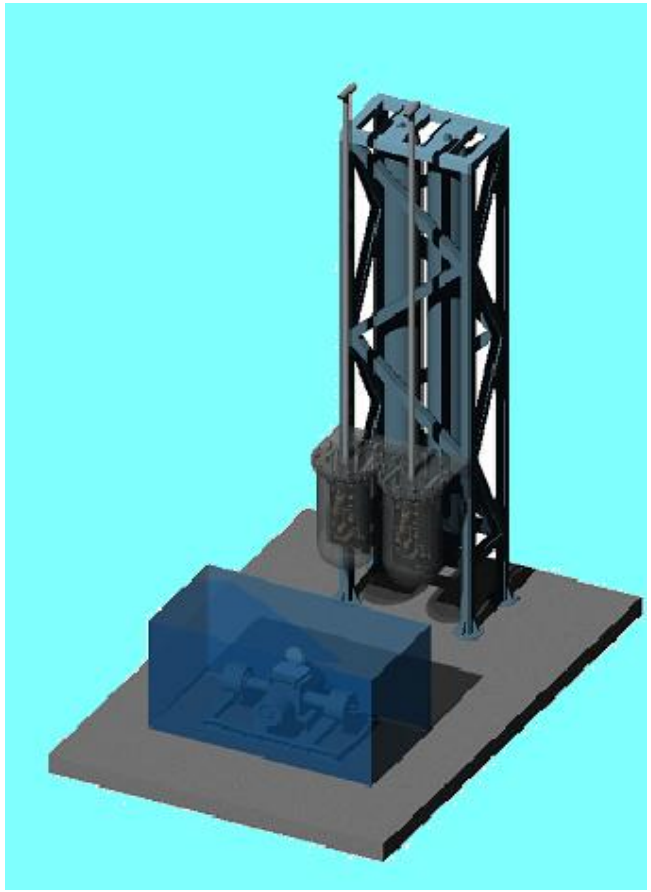
Fuel Blend	Acceleration to 60 mph (secs.)	Fuel Economy (miles/gge)	Range (miles)
CNG	10.10	23.3	122
15% H/CNG	10.97	22.6	110
30% H/CNG	12.68	23.5	102

Generation II Station Design

- **Driven by commercial fueling station design requirements**
  - **Reduced setbacks to allow siting on a commercial corner**
  - **Reduced operator training to allow operation by service station personnel or vehicle operators**
  - **Reduced hazards to minimize the maximum potential accident**
  - **Multiple layers of safety to significantly reduce operating risk**

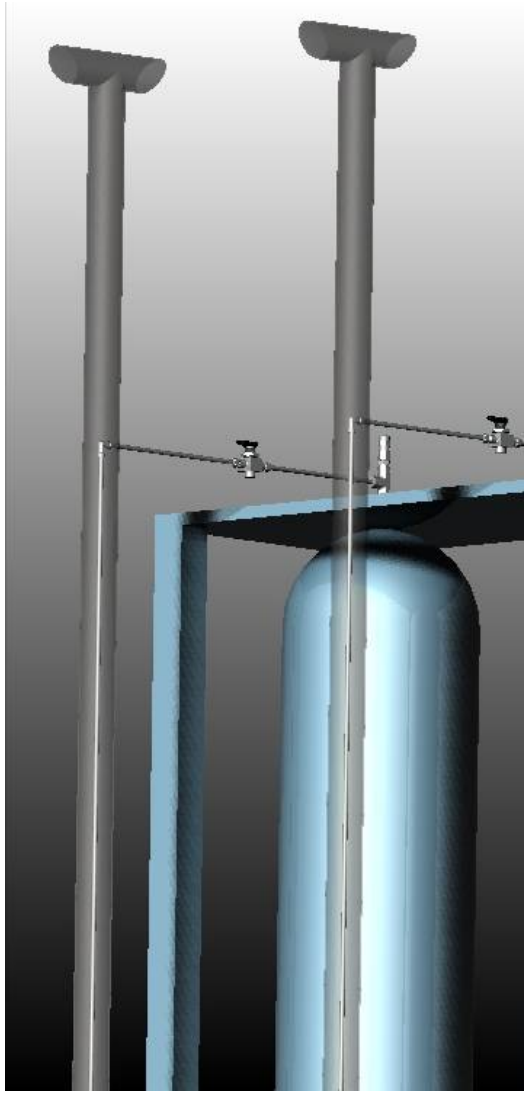
Generation II Station Design

- Coaxial Containment System™
- Expandable modular design
- Envelopes most severe environmental conditions
- Exhaustive safety analysis to support permitting
- Zero setback requirements for flexible siting
- Shop assembled skid design
  - Assembly by ASME shop
  - Field welding minimized



Generation II Station Design - Coaxial Containment System™

- **Double wall piping system**
  - **Shields process piping within a pressure containing pipe**
  - **Contains pressure waves resulting from any gas ignitions**
  - **Redirects any detonations to benign location**
  - **Allows inerting of annulus to prevent gas ignition**
  - **Eliminates need for blast setback**
  - **Protects process pipe from vandalism**



The hydrogen station, vehicle testing, and prototype dispenser testing reports; this presentation; and the online Alternative Fuel (Hydrogen) Pilot Plant monitoring system are available via:

http://avt.inl.gov

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